Title: New Worlds Through the Electron Microscope

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—Courtesy: Westinghouse Electric Mfg.

Sorting machine-mass spectograph segregates gas molecules according to their masses

NEW WORLDS THROUGH THE ELECTRON MICROSCOPE

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"The greatest extension of human vision since 1677 when Anthony van Leeuwenhook first focused spermatozoa under his crude lens is the electron microscope."

That statement appearing in Life Magazine frankly signifies the importance of the development of the electron microscopy. The essence of microscopy is to reproduce the object in greater detail. Magnifications ten-fold greater than with the ordinary light microscope are possible with this new instrument. Microscopic details smaller than one-half the wave length of visible light are beyond the limits of human sight. However, in the electron microscope designed and built by Radio Corporation of America at Camden, New Jersey, a wave length one hundred thousand times shorter than that of light brings these details into sharp definition.

On the basis of conventional diagrams in optics, it is reasonable to say that infinite magnifications should be possible. This appears feasible, for in these diagrams light is represented by straight lines. However, light has the characteristics of a wave motion and can thus bend around very minute particles. This phenomenon becomes very important as the particles become extremely small.

The development of the electron microscope began in 1931 when M. Knoll and E. Ruska constructed one which consisted of two lenses. Improvements were later made by E. Ruska and L. C. Marton in Belgium. These were followed by other improvements which refined the instrument and eliminated many of the time- and labor-consuming operations.

Scientists had for many years cherished the hope that some form of radiation would be discovered which would have a wave length much shorter than that of light, and would give greater magnifications in microscopy. During the last decade of the nineteenth century both electrons and x-rays were discovered, and these were at once suggested as possible solutions of the problem. On account of their effects on photographic plates and their power to penetrate matter, x-rays were from the first thought to be a form of light, but all attempts to make them capable of refracting failed.

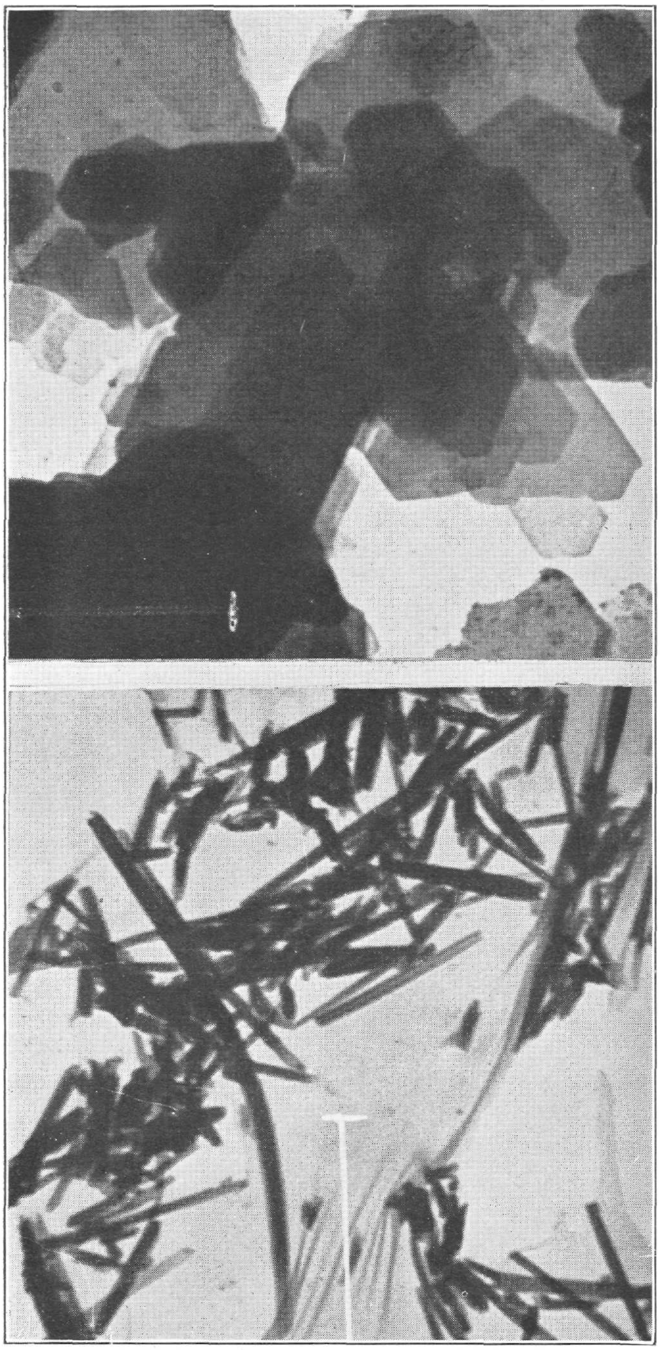
Light has become known within the last few years as a type of energy. A good example of this is the photo-electric cell. When the beam of light of this cell is broken, another circuit is made and any of a variety of mechanisms can subsequently be operated. With light being a type of energy and having a wave form, physicists wondered if a beam of electrons would have the same dual properties as that of light. A beam of electrons consists of a stream of small negatively charged particles having a mass about one two-thousandths that of the hydrogen atom.

As a ray of light passes through an optical lens, the ray is always refracted. This phenomenon makes possible the ordinary optical microscope. A beam of electrons cannot pass through an optical lens; consequently, another method must be used to refract them. It was already known that magnetic fields had a decided effect on protons and electrons and that the desired effect could be accurately controlled. Therefore, magnetic fields can accomplish the same results with electron beams that optical lenses do with light.

The reason that the electrons are accelerated to high speeds is the fact that the wave length of the electrons becomes shorter as their speed increases. Their short wave length makes possible the high magnifications.

The tungsten cathode is in the shape of a hairpin and is mounted at the lower end of a rod. This may be raised or lowered within a cathode shield by means of an adjusting screw and a bellows arrangement. The possible adjustment is advantageous for two reasons: first, the efficiency of the cathode is increased, and, second, the cathode may be drawn up into the shield so that only the electrons from the tip might be able to escape. The electrons leaving the cathode are accelerated downwards and pass through the anode, the deflection plate, and the condensing lens. The anode and deflection plate are useful in controlling the beam of electrons, while the condensing lens reduces the cross section of the beam. As the electrons hit the particles of the specimen, the electrons are scattered or absorbed in proportion to the thickness and atomic properties of the particles. This is exactly what happens when light hits the object in the visual microscope.

The absorbed electrons, upon leaving the object, pass through the aperture of the objective lens



—*Courtesy: Engineering Experiment Station News*

Clay minerals through electron microscope; upper Kaolinite; lower Halloysite.

and are focused by its strong magnetic field upon the first image screen. The electrons from any desired part of the object may be directed through an opening in the first screen into the second or projection lens. The electrons are again focused by the magnetic field of this lens to form a much greater magnified image on the second screen. The image at this point may either be seen on the flourescent screen or photographed by replacing the screen with a camera. A high magnification is obtained in each lens by having a large ratio between image distance and object distance. The total magnification is, of course the product of the magnifications produced by each lens.

In order to see the characteristics of the specimen, it is necessary to suspend it on an electron optically transparent film. A very satisfactory membrane can be made with a solution collodion and amyl-acetate. Drops of this solution are allowed to fall on a surface of water. The amyl-acetate evaporates quickly and leaves a film of collodion on the water. The object is then placed on the film, which is about one millionth of a millimeter in thickness. The film and object are then placed between two small disks of very fine wire mesh which serves to support it.

Since the magnifications are so great, it would require a good deal of patience to adjust the specimen until the desired part is focused. Therefore, a periscopic device has been built into the instrument.

When looking at the final image, the operator can, by moving his eyes sideways, look into the periscope and see the intermediate image. This device aids the operator a great deal in his study of the specimen.

The air must be exhausted from the microscope because the electrons would bump into the comparatively large molecules of air and be stopped. Therefore, the main body of the microscope is exhausted, and the specimen is entered and removed by the airlock so that it does not interfere with the vacuum in the main body of the instrument. The airlock is similar to the escape chamber of the submarine. After the specimen has been placed in position, the air is exhausted from the lock and it is connected to the rest of the microscope. Before removing the specimen, the lock is disconnected from the main body of the instrument, and it is then opened. The time taken by the pump to evacuate the chamber is about two minutes. Likewise, the plateholder for taking photographs is placed in an airlock situated at the bottom of the instrument.

What is actually seen in the microscope is a flourescent screen which is about $3\frac{1}{2}$ x $4\frac{1}{2}$ inches in size. The image that is seen on this screen is produced by the electrons hitting it. For each electron that hits the screen there is a tiny flash. Consequently, the light parts of the image represent the less dense parts of the object through which the electrons have passed.

The electron microscope is opening a new world, a world that has never been seen before. Therefore, research workers using the instrument will have to advance slowly from the known to the unknown. Whooping cough germs which are at the limit of the visual microscope can be enlarged

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with the electron microscope to the size of footballs and their internal structure studied.

So-called filtrable viruses that cause a series of diseases probably have been seen for the first time, but they have not yet been identified. They are called filtrable diseases because they pass through filters, and their presence can only be proven by producing the disease with the filtrate.

Its industrial applications will probably be just as important as the medical ones. Industries making cement or making rubber are anxious to find out what lies beyond the visual microscope. As matter of fact, any industry that refers to photomicrographs of specimens will be extremely interested in this new instrument.

The electron microscope should prove another boon to mankind. With magnification of 100,000 diameters as compared to 6,000 diameters with the light microscope, its possibilities are enormous. Just as Anthony van Leeuwenhook gazed into his simple microscope to see a new world, so will those who gaze into the electron microscope see a world new in the realm of microscopy.